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EPIDEMIOLOGICAL STUDIES ON DIPHTHERIA
IN BALTIMORE
1920 - 1921

Submitted by Reginald M. Atwater to the Department
of Epidemiology of the School of Hygiene and
Public Health, Johns Hopkins University,
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EPIDEMIOLOGICAL STUDIES ON DIPHTHERIA IN BALTIMORE FOR THE EPIDEMIC SEASON OF 1920-1921

In view of the really meagre knowledge which we possess concerning the fundamentally important facts in the natural history of the diphtheria bacillus, it seemed wise to undertake a study of this disease of which this report represents a small part. The work was undertaken under the Departments of Epidemiology and Immunology of the School of Hygiene and Public Health and was directed by Drs. W. H. Frost and C. G. Bull to whom I am indebted for an opportunity to collect this information.

Since there was a limited time in which I could work, it has been necessary to include an analysis of data on cases other than those which I personally visited, in order to secure a sufficient volume of cases to make the findings significant. The group of 100 cases of known diphtheria individually visited and studied is supplemented by the briefer data available from the Health Department for the analysis of chronology, geography, mortality and the color, sex and age distributions. The following outline summarizes the subjects of the paper:

Outline of this study of the epidemiology of diphtheria in Baltimore for the epidemic period of 1920-1921:

The 863 cases reported between August 1, 1920 and January 15, 1921:

- Geographical distribution.
- Chronological distribution.
- Force of mortality.
- Color distribution.
- Sex distribution.
- Age distribution.
- Incidence among the Schick susceptible population.

The 100 cases in the western half of the city studied intensively:

- Diagnosis; elimination of doubtful cases; selection of data.
- Prior to exposure to diphtheria, with a comparison of diphtheria, typhoid fever and poliomyelitis.
- Milk supply and use of milk.
- Sanitary condition of household.
- Family infection; secondary cases in relation to sex and age.
- Special observations made during the study.

The Geographical Distribution of Diphtheria in Baltimore, 1920-1921.

For the purposes of this study the original period studied, from October 15, 1920 to January 15, 1921, was found to be so located in the course of the epidemic as to represent merely the period of highest incidence, as will be seen from referring to the accompanying figure of the curve of the epidemic. In studying the origin and spread of the disease from the geographical standpoint it

is essential that the first part of the season's epidemic curve be included. Accordingly a study was made of the period between August 1st and October 15th and it was ascertained that in this time the lowest point of the epidemic occurred in all wards of the city. This additional period with its 162 cases was therefore included in the following table which shows the data for each ward.

It is at once apparent that the epidemic has had different periods in the several wards, but further study of these ward reports by days and weeks becomes so complicated in detail involving different geographic and population features, that exact conclusions of the methods of spread cannot be reached. In certain wards like 24, 25 and 22, it is clear that the prevalence of diphtheria has differed from that of the city as a whole, but otherwise the conclusions to be reached are uncertain.

In order to analyze the complicated interrelations of the wards the following method has been adopted: Geographical groupings have been made of such wards as are most intimately associated by topographical situation and the location of the business district. These groups are four in number and have been chosen after a study of the manner in which the pins on the diphtheria spot map are condensed in certain areas. Such natural boundaries as the

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northwest and middle branches of the Patapsco River, Druid Hill Park and Jones Falls and the artificial but none the less real isolation of the wards by the central business district make apparent groups of wards on the spot map. The validity of these groupings is strengthened when it is considered that the large majority of cases of diphtheria are among the children whose limitation of movement to their respective districts is much more marked than with adults and whose school districts do not lie in more than one of these sections as selected.

The districts as made up of groups of wards are as follows:

Eastern Group: Wards 1, 2, 3, 5, 6, 7, 8, 10, and 26.
Southern Group: Wards 23 and 24.
Western Group: Wards 15, 16, 20, 14, 11, 17, 18, 19, 4, 21 and 22.
Northern Group: Wards 9 and 12.
(Wards 25, 27, 28 and 13 do not lend themselves to any grouping).

In the accompanying tables the incidence of reported cases by weeks is shown for each group in the table as well as for the city as a whole and the cases are plotted both numerically and as rates.

It is evident from these epidemic curves in the different sections of town that the eastern and western groups are similar to the whole city both as to the time of the epidemic and as to the case rate. On the other hand,

the southern and northern groups (each made up only of two wards) have had an epidemic with a mode quite different from the entire city and an epidemic of much higher rate than that of the whole city.

In other words, the diphtheria in Baltimore, although spread widely throughout the city, has had different prevalence in the various sections, both as to time and case rate. It does not seem that differing age distribution would account for these observed differences in the four sections. Race distribution has been adjusted for each ward by computing the cases for the white population only and it seems clear that the location of the negro districts has little to do with the prevalence of the disease among the white population.

Chronological Studies on the Epidemic of Diphtheria in Baltimore.

The object of this study is to ascertain whether the spread of diphtheria in this city is of a radial sort from a single or at most a few sources, or whether the spread is from multiple foci so distributed that the epidemic was virtually simultaneous in all parts of the city.

No entirely satisfactory geographical groupings of the wards could be made for this purpose, since contiguous wards must inevitably be classified under different groups. The preceding section has dealt with the epidemic

in different geographical sections. Accordingly a chronological grouping was made which offered more evidence of applicability.

The median case for the epidemic period August 1, 1920 to January 15, 1921, was ascertained for each ward and the date of report of that case was taken as the best average of the epidemic curve in that ward. It was found that the dates of the median cases covered a period from October 22nd for Ward 27 to December 18 for Ward 5. These dates fell into four natural periods, as will be seen from the accompanying table.

Baltimore Wards arranged in order of the date of the median case:

Ward	Median Case Date	Ward	Median Case Date
27	October 22	6	November 22
28	24	10	24
25	24	13	24
24	25	19	24
23	27	18	27
4	29	7	27
3	November 11	21	28
26	13	11	29
1	15	17	December 1
2	15	8	5
9	15	22	5
16	19	15	9
12	20	14	12
20	20	5	18

When the dates of these median casea are compared with the distribution of the Wards it is seen that the outermost wards of the city passed the mid-point of the epidemic in the earliest group, and conversely that the wards near

the center of the city had in general a later epidemic. The more sparsely settled periphery of the city had an earlier median case than the more densely settled central portion of town. It can be seen that the Locust Point section (Wards 23 and 24) and the section including Wards 9 and 12 had uniformly earlier median cases. This fact is obvious from the epidemic curves of the whole city and those of the eastern and western sections.

The case rates, using as a basis the 1920 white population in each ward, when arranged chronologically, according to the dates of the median case, shows an apparent random prevalence among the Wards. That is, the case rate does not show any decided tendency to change as the date of the median case moves among the wards from October 22nd to December 18th.

The significant feature of this case rate in the wards is only brought out when the results are grouped. The same convenient chronological groups used in the time distribution serve equally well for this study of case incidence. The table accompanying shows the case incidence among the wards of each group to be the highest in the group having the earliest median case date and lowest in the grouping having the latest median case date. (See page 9.)

It seems rather significant that this case rate

figure should decline so regularly as the date of the median case in the wards advanced. The change of 25% between the extreme rates seems a definite fact which indicates a decline in the ability of the organism of diphtheria to produce clinical cases of the disease as the time increases from the beginning of the year's epidemic. It is, of course, possible that an increasing immunity among the population would account for this change.

The table showing the wards arranged in order of their case rates does not demonstrate the facts just mentioned very strikingly, since there is considerable deviation from the average of the group when the small number of cases per ward are considered.

The conclusions to be drawn from the chronology of the epidemic in brief are as follows: The disease has a striking seasonal variation in Baltimore which is similar to the seasonal curve of other large cities. The disease breaks out simultaneously, it would seem, in almost all sections of the city during September. Closer analysis shows that this outbreak comes decidedly earlier in some wards and in some groups of wards than in others. There is a marked difference in the case rate in different wards and different sections and the case rate is highest in the wards which pass their mid-point of the epidemic

THE CASE RATES OF DIPHTHERIA PER 1000 WHITE POPULATION IN BALTIMORE, AUGUST 1, 1920 - JANUARY 15, 1921. WARDS ARRANGED IN ORDER OF THE MEDIAN CASE AND GROUPED ACCORDING TO THE DATES OF THESE MEDIAN CASES

Ward	White Population	Cases Reported	Case Rate	Chronological Groupings	
				Cases Reported	Case Rates
27	34,599	58	1.68	169	1.58
28	7,773	2	0.26		
25	15,552	19	1.22		
24	24,533	67	2.73		
23	14,074	13	0.92		
4	10,184	10	0.97		
3	17,413	23	1.32	335	1.44
26	36,280	70	1.93		
1	33,089	43	1.30		
2	20,511	36	1.75		
9	29,582	46	1.56		
16	29,138	34	1.17		
12	31,303	50	1.60		
20	36,002	33	0.92		
6	27,735	43	1.59	230	1.32
10	16,766	10	0.60		
13	33,003	43	1.30		
19	19,421	12	0.62		
18	14,581	28	1.92		
7	27,980	36	1.28		
21	16,716	32	1.92		
11	14,326	15	1.05		
17	4,938	11	2.23		
8	35,643	44	1.24	130	1.18
22	10,045	11	1.10		
15	40,245	44	1.10		
14	12,620	17	1.35		
5	11,062	14	1.26		
Total	625,074	864	1.41		

earliest. The more sparsely settled wards had , in general, an earlier epidemic with more clinical cases than wards densely settled. The case-rate decline as the date of the median case advanced is regular and seemingly significant.

These findings indicate that diphtheria in Baltimore is a city-wide disease which is not simultaneous in its course throughout the city. Whether the spread be radial or not is not definitely certain, but it seems not to spread radially from a single or from relatively few foci, as judged from our somewhat gross morbidity data. In this sense the epidemic does not resemble Poliomyelitis closely in its course through a metropolitan area where the radial nature of its spread has been clearly demonstrated. From this fact it seems safe to conclude that the virus which is responsible for the epidemic is not an exotic strain introduced at one point. More likely, it is rather an ubuquitous organism, as one would suppose from the observations which have been made on its life history and the disease is probably a multiple focus type in its epidemic form.

As regards the force of mortality operating during this period, a summary of the deaths which occurred in Baltimore between October 15, 1920 and January 15, 1921 shows 36 deaths with cause assigned to Diphtheria

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and Croup. Comparison with the 20 years preceding show in these same months an average of 37.6 deaths from diphtheria, (maximum 19, minimum 15), so this period under study is rather typical for Baltimore in this respect. Of these 36 deaths two were unreported as cases, so there are 703 known cases of diphtheria in this three-month period responsible for 36 deaths, or a case fatality of 5.1%.

Quite obviously, this means of estimating a case fatality depends for its accuracy very largely on the completeness of reporting, which is assumed to be good as regards definitely clinical cases of diphtheria in Baltimore. It is interesting to note that the New York State report for November, 1920, a period included in the interval here considered, shows the case fatality to be as follows:

New York State	5.3%
New York City	5.6%
State outside New York City	5.1%
Cities	5.1%
Rural	5.2%

The only other comparable figures at hand show Chicago's case fatality to have been in May 7.5% and in November and October 8.1%, while Winnipeg's records for 16 months show a figure of 6.1%. From these data it seems fair to assume that the force of mortality is within usual limits for American cities.

A study of the months in which the annual epidemic mode (deaths) occurred during the period 1860-1919 (60 years) shows the following percentage distribution of modes in the several months:

September	1.45%
October	17.40%
November	20.30%
December	27.50%
January	17.40%
February	5.80%
March	5.80%
April	4.35%

Nineteen hundred and twenty-twenty-one has two peaks falling in December and January. The seasonal distribution of the mode is within the usual limits for Baltimore.

THE COLOR DISTRIBUTION OF THE CASES OF DIPHTHERIA

From the table showing the case rate for each age, sex and color it will be seen that the colored population has a decidedly lower case incidence than the white. This was evident from the gross figures in which the negroes contributed only 17 of the 701 cases, while they constitute 15% of the population in Baltimore. In terms of rates, the colored population had an incidence of 0.157 cases per 1000 during the same months when the white population had an incidence of 1.092.

Other comparable figures are not easily found for cases, although the favorable death rate among negroes

is evident from the Registration Area mortality statistics. In the Surgeon General of the U.S. Army Reports for 1919 and 1920 the following data are obtained:

Diphtheria Admissions			Annual Rates per 1000 mean strength		
1919	U. S.	Europe	1920	U.S.	Europe
White	2.78	2.33	White	2.62	2.82
Colored	1.04	0.46	Colored	0.78	1.39
Total	2.62	2.31	Total	2.47	3.31

These bear out the Baltimore rates, though there is in Baltimore the more striking difference because of a population containing a much higher percent of diphtheria susceptibles.

The curves herewith showing the relative color incidence of cases show that this significant difference is susceptibility holds good at all ages and for both sexes. The mechanism of this immunity was not within the scope of this investigation and there was not enough experience with the negro cases to warrant any conclusions. The whole question deserves careful study with numerous Schick tests at the different ages. Certainly the negroes were exposed to the disease, for they meet the white population at every turn and there were isolated cases among their own number. To be sure, the school populations are separate for their actual school work,

but that appears to be all. No data have been found concerning the occurrence of diphtheria bacilli among any considerable number of colored persons.

There are several observations recorded in the last section of this paper which give a strong indication that there are other factors than that of antitoxin in the determination of immunity to the disease. The relative importance of these -- let us say antibacterial substances in the immunity of the negroes should not go undiscovered.

THE SEX DISTRIBUTION OF CASES OF DIPHTHERIA IN BALTIMORE

The following tables show that there is a considerable difference in the sex rates at different ages for Baltimore. The graphs herewith show white cases only. This sex difference is to be expected, although the total figures for each sex show no difference. However, the difference observed in the younger years may be explained, the usual predominance among adult females by common consent is ascribed to their greater exposure in their duties as nurses to sick children. The excess of femal over male cases in the ages 1-4, inclusive, and that of males over females in the ages 7-9, inclusive, is interesting but possibly accidental in origin.

The comparative figures with Providence show definitely the tendency for females to have more cases

in later life, but the differences in early life are not parallel. Why there should be this diversity is not apparent. The graph showing the sex ratios compares these two cities in a convenient way. The Providence data cover cases reported between 1896 and 1913, as shown in the annual report for 1913. The Baltimore data are for the period October 15, 1920 - January 15, 1921.

	PROVIDENCE			BALTIMORE		
Ages	Males	Females	Male Ratio Females =100	Male Ratio Females =100	Females	Males
0-4	975	847	115.0	100.0	135	135
5-9	1071	1210	88.8	135.0	109	147
10-14	400	480	83.6	71.3	42	30
15-19	127	165	77.0	111.0	9	10
20 & over	249	416	60.0	40.4	47	19
Total	2822	3118	90.7	100.0	342	341

	PROVIDENCE		BALTIMORE	
Ages	% All Males	% All Females	% All Males	% All Females
0-4	34.5	27.2	39.6	39.5
5-9	38.0	38.7	43.2	31.9
10-14	14.2	15.4	8.7	12.3
15-19	4.5	5.3	3.0	2.6
20 & over	8.8	13.4	5.5	13.7
	100.0	100.0	100.0	100.0

THE AGE DISTRIBUTION OF DIPHTHERIA CASES

The accompanying table and graph speak for themselves. The distinct peaks at 3 and at 6 years are possibly worth special mention, the latter coming when school begins for most children and the former may be assumed to occur at a time when the motility and consequent exposure of the children greatly increases. It is significant that these same age peaks occur in the Edinburgh results when summarized over a number of years, but unfortunately for this assumption, in Edinburgh the children begin school considerably earlier than in Baltimore. According to Sir Arthur Newsholme, this age is often as early as three years.

It is interesting to compare the figures for Providence and Baltimore in the matter of age distribution and the following tables and graphs show the number of cases occurring in the stated periods for each specified age or age group. They also show in parallel columns the percentage of the total cases which occurred at each age.

It is seen from these figures that the age distribution of diphtheria cases in Baltimore is quite different from that of Providence. The Baltimore epidemic of 1920-21 show a preponderance of cases over Providence in the years up to seven and Providence shows a preponderance

THE AGE DISTRIBUTION OF DIPHTHERIA CASES IN PROVIDENCE 1896-1913 AND IN BALTIMORE 1920-1921

Age	BALTIMORE		PROVIDENCE	
	Number of Cases	% of Total	Number of Cases	% of Total
Under 1	12	1.7	110	1.8
1	47	6.7	286	4.8
2	65	9.3	456	7.7
3	82	11.8	445	7.5
4	70	10.0	525	8.8
5	65	9.3	506	8.5
6	72	10.2	546	9.2
7	47	6.7	491	8.2
8	45	6.4	420	7.1
9	31	4.4	318	5.3
10	21	3.0	267	4.5
11	17	2.4	206	3.5
12	19	2.7	179	3.0
13	7	1.0	126	2.2
14	10	1.4	102	1.7
15-19	20	2.8	292	4.9
20 & over	71	10.2	665	11.3
Total	701	100.0	5940	100.0

thereafter. The disease in Providence thus is prevalent later in life than in Baltimore. It is striking in this connection that the death rate from diphtheria in Providence is consistently higher, generally twice as high, as Baltimore and that there is about four times as high a secondary attack rate in Providence as in Baltimore. Why this apparently greater severity in Providence should operate in the older ages is not at all clear. Although these figures have not been expressed as rates for each age, it is not apparent that

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It seemed of significance to convert this curve of Schick susceptibles into the Baltimore population and

any difference in age distribution of this magnitude of the population exists in the two cities.

THE INCIDENCE OF DIPHTHERIA AMONG THE SCHICK SUSCEPTIBLE POPULATION

In a summary of the published results of Schick teats, Mr. W. T. Fales has constructed a table of the combined results of such observations as lend themselves to cpmparison. Unfortunately, the age rubric is not given by single years or in similar multiples of years by many observers, but the following table summarized from the sources below gives the percentage susceptibility at each age group indicated.

The sources of combined Schick test results are as follows:

2700 cases - Three large orphan asylums in New York - Zingher.
1076 cases - Home for Hebrew Infants, New York - Blum.
796 cases - Scarlet Fever patients, Willard Parker Hospital, N.Y. -- Zingher.
670 cases - Chicago Health Department - Burndesen.
497 cases - New York Foundling Asylum - Zingher.
494 cases - Hebrew Infant Asylum, New York -Zuckerman.
429 cases - New York Protectory - Zingher.
425 cases - Metropolitan Hospital - Moffatt and Conrad.
338 cases - St. Louis Children's Hospital - Moody.
171 cases - Institute of Mercy - Zingher.
151 cases - Dominican Convent - Zingher.
123 cases - Home for Jewish Children, Boston -Linenthan and Rubin.
90 cases - Philadelphia. Kolmer and Moshage.

It seemed of significance to convert this curve of Schick susceptibles into the Baltimore population and

having secured for each age the susceptible population, to compute the rate for such cases as actually occurred in each age group. For this purpose the white population only was used. This was for two reasons: (1) The Schick results quoted were as far as known from white children, and (2) the white population was contributing cases of diphtheria at a rate nearly ten times that of the negro population in Baltimore, so the negro portion can be reasonably excluded.

THE INCIDENCE OF DIPHTHERIA IN BALTIMORE BY AGE GROUPS - AMONG PERSONS SUSCEPTIBLE TO DIPHTHERIA AS INDICATED BY THE SCHICK TEST

Age Groups	Per Cent Positive Schicks in Combined Reports	Baltimore White Population	Assumed Susceptibles	Cases in Baltimore for 3 Months	Rate per 1000 Susceptibles
0-1	36.4	11,868	4,320	11	2.55
1	54.6	11,244	6,139	47	7.63
2-3	47.2	25,604	12,085	142	11.7
4-5	32.8	24,661	8,089	134	16.6
6-7	25.4	22,804	5,792	116	20.0
8-9	24.1	21,770	5,247	76	14.5
10-11	26.9	22,187	5,968	36	6.0
12-13	26.3	22,445	5,903	26	4.4
14-15	16.2	24,006	3,889	14	3.6

(See accompanying graph.)

It is unfortunate that the Schick results used in this study are not from observations made among Baltimore children, but such are not available on any scale. Most of the sources of these Schick tests are institutions

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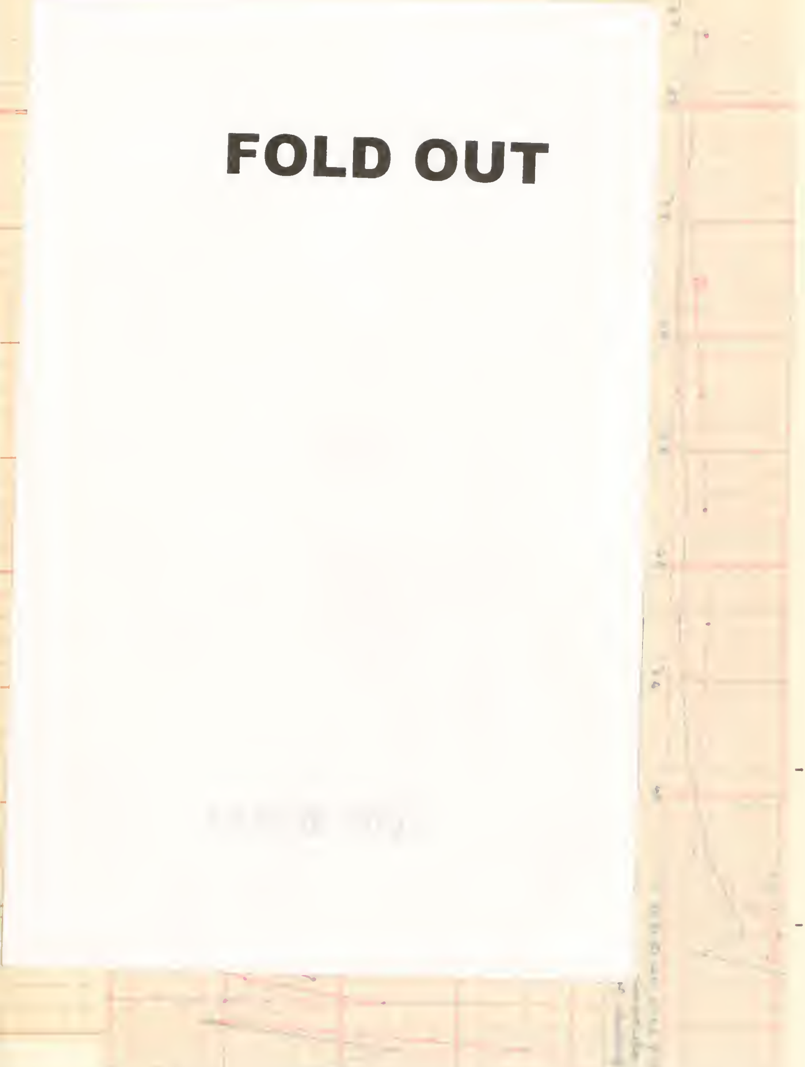

which may confuse the result of this study, is the

where it is much easier to test a large number of children. Whether children in a general population show a difference susceptibility curve from these institutions is a point that is still obscure. It seems reasonable, however, to regard this study of the rate of incidence among Schick susceptibles as free from gross error.

Assuming the validity of this data, by this method the susceptibility of all the children as regards antitoxin in the blood is reduced to a common denominator. If the incidence of disease for a given individual depends, as is generally assumed, on the two factors susceptibility and exposure, then this curve should indicate the varying exposure of the different ages to the infection. While it is conceivable that the exposure of an individual increases rather arithmetically from birth to the seventh year, as indicated by this graph, it is not apparent why his exposure to diphtheria should decrease thereafter for at least eight years. It would be interesting to know whether there are sex differences in this Schick immunity which would explain the disparity of incidence in the sexes at various ages.

Aside from the possible errors noted above which may confuse the result of this study, is the

probability that the Schick test is not an index of the total diphtheria immunity. This is indicated by the fact that 75 percent of individuals who recover from diphtheria without antitoxin have positive Schick reactions (Park), so that their immunity is probably antibacterial rather than antitoxic. Also the finding in our own series (Case 1, No. 5) of diphtheria bacilli of proven virulence in the nose and throat of Schick positive individuals serves to strengthen this view. If this other-than-antitoxic immunity --call it antibacterial for convenience -- be developed only after age seven, the curve of the table above would be quite understandable. Otherwise the reason for a decreasing incidence among the susceptible children from the seventh to the fifteenth year is quite obscure.

This completes the extensive studies on the 863 cases reported between August 1st and January 15th. The intensively studied group of 100 cases follows.

ONE HUNDRED CLINICAL CASES OF DIPHTHERIA IN WESTERN BALTIMORE STUDIED INTENSIVELY

Selection of the Data:

The attempt was made to select for this paper the first 100 cases studied which could reasonably be classified as true cases of diphtheria in a clinical sense. No cases are included in this series which did not show at

least morphological diphtheria bacilli in nose or throat and which were not true diphtheria in the opinion of the attending physician.

In selecting these 100 cases it was necessary to exclude 17 cases, as follows:

> Carriers only, detected in routine school examinations, 6. (Cases 4, 9, 13, 28, 81 and 100.)
> Incomplete cases, 3. (Cases 20, 26 and 103.)
> Diagnosis of clinical diphtheria withdrawn or doubtful, 5. (Cases 39, 43, 44, 85, 109.)
> Out of district and not followed, 1. (Case 71.)
> Patient died before visit, 1. (Case 66.)
> Patient removed before visit, 1. (Case 101.)
> The two fatal cases in this series (66 and 26) are necessarily omitted because of the lack of enough complete data to justify their use for comparison.

The 100 cases, then, represent a series of true clinical diphtheria occurring over a period of about two months, November, 1920 to January, 1921, in Baltimore.

DATA REGARDING THE PRIOR EXPOSURES TO SOURCES OF INFECTION OF 100 CLINICAL CASES OF DIPHTHERIA

Information was obtained in each case by careful questioning regarding the contacts of the patient and his associates with known sources of diphtheria and of suspicious exposures and situations. In classifying this data some cases have two or more possible sources and the most direct source is assumed for purposes of classification. The following table sets out the results of the 100 cases

in which a consistent effort was made to ascertain the source:

Cases giving history of exposure to a known case:	
Directly	15%
Indirectly, i.e. through another individual	9%
Cases giving history of exposure to illness suspected of being diphtheria:	
Directly	8%
Cases giving history of exposures to known carriers or convalescent cases:	
Directly	3%
Indirectly	2%
Cases giving only a history of exposure to the general public:	
Directly	52%
Indirectly	11%
	100%

Since the contact data obtained in this study was obtained with similar diligence and thoroughness to that of some recent Poliomyelitis and Typhoid Fever studies, it seems interesting to compare the results found in the contact source of diphtheria to that found in these other diseases. So far as is known, there are not available comparable studies for other diseases. The striking similarity of these studies was unexpected and possibly significant in that, as far as this method indicates, unrecognized sources are responsible for the majority of the cases.

Comparisons of the exposure histories obtained in diphtheria, poliomyelitis and typhoid fever epidemiological studies:

> Diphtheria data from the series of 100 cases reported herewith.
> Poliomyelitis data from P.H. Bulletin 91, p. 199 (rural group) and p. 157 (city group).
> Typhoid Fever data from Hygienic Laboratory Bulletin 44, p. 52 and H.L.B. 35, p. 53.

	DIPHTHERIA	POLIOMYELITIS		TYPHOID
	City Group	Rural Group	City Group	City Group
Total cases investigated	100	263	328	1389
Cases giving history of a direct contact with previous definite or suspected case	23%	34.6%	21.3%	11.65%
Cases giving history of an indirect contact with a previous definite or suspected case	9%	8.4%	7.6%	4.75%
Cases giving a history of an association with known carriers	5%	--	--	--
Cases giving a history of contact only with the general public	63%	57%	70.8%	83.6%

THE SOURCES OF THE MILK SUPPLY AND THE USE OF MILK OF THE 100 CASES

The milk source of the 100 cases was as follows:

City Dairy, all branches,	33	Clover Farm Dairy	1
Western Maryland Dairy..	26	Ravine Dairy...........	1
Fairfield Farms Dairy...	17	Zaizer Dairy...........	1
Unknown	7	Myrtle Dairy...........	1
Canned milk only	5	Malleny Dairy	1
Highland Farm Dairy	2	Spickler Dairy	1
Oak Grove Dairy	1	Litzaus Dairy	1
Several Dairies	1	Cloverland Dairy	1
Walnut Grove Dairy	1	None...................	1
			102*

*Two families received milk from two recorded sources.

The only data available on the amount of milk sold by these dairies is an estimate of the daily output appended to the annual inspection card. Fortunately, this inspection was made in December, 1920, during this investigation, and the figures are fairly accurate. The following table shows the ratio of cases to output for the three dairies having significant representation:

	Diphtheria Families Supplied	Daily Output in Gals. of Milk & Cream	Cases per 1000 Gals. Milk & Cream.
City Dairy	33	11,000	3.0
Western Maryland Dairy	26	9,030	2.9
Fairfield Farms Dairy	17	3,800	4.5
Total for three dairies	76	23,830	3.2

(All milk sold pasteurized at 145° F. for 30 minutes.)

As to the extent of use of milk by these 100 diphtheria patients, the following figures were obtained:

As a beverage	49%
None	14%
On cereals and coffee...	36%
Unknown	1%

It is interesting to compare these results in the extent of use of milk with those obtained in Washington in the study of typhoid fever: (Hygienic Laboratory Bulletin 78, page 147, June, 1906 -- December 1909 studies.)

	Milk as Beverage	Only on Cereals Tea and Coffee	None and Unknown
Washington- 2702 persons, Typhoid	49.2%	20.2%	30.6%
Baltimore - 100 persons, Diphtheria	49.0%	36.0%	15.0%

Inasmuch as the age distribution of these diphtheria cases was different from that of the typhoid fever cases, it is rather to be expected that since the diphtheria patients are younger they would drink milk more freely. These figures show a smaller percentage of the sick in the beverage class than would be expected if milk would be a significant factor in the spread of diphtheria. In view of the even distribution of cases among the dairies, it seems reasonanle to conclude that Baltimore's diphtheria is not due in any large way to the milk supply.

THE SANITARY CONDITIONS OF THE HOMES OF THE 100 CASES EXAMINED

As will be seen by reference to the attached sample of the investigation form, a record was made of each case as to the general sanitary condition of the household. Four groups were used: Excellent, Good, Fair and Poor. The 100 homes showed the following scores:

Excellent	18%	Fair	38%
Good	33%	Poor	11%

The eight secondary cases in this series show the following distribution among the four classes of sanitary condition:

Excellent .... 3 or 37.5%   Fair .... 2 or 25.0%
Good .... 3 or 37.5%   Poor 0

If one were to judge from this small number of instances, it would seem unlikely that poor sanitary conditions had any great effect on the rate of incidence of secondary cases. To the field observers, it seemed evident, at least in the case of children in the family, that they were all freely exposed to the infection before any isolation measures were established in spite of the sanitary status of the household. This would imply that the occurrence of clinical diphtheria is dependant on the presence or absence of specific immunity rather than upon exposure to infection. A comparison of these data with those obtained in investigations of poliomyelitis and typhoid fever does not show any significant features, partly because of the rather uncertain bases for comparison.

THE SECONDARY CASE RATE (SECONDARY ATTACK RATE) OF DIPHTHERIA IN BALTIMORE WITH A COMPARISON OF THE PROVIDENCE EXPERIENCE

The tables presented on the following page show that the experience among these 100 cases in Baltimore has been an attack rate of secondary cases much lower at all ages than Providence and for several ages one quarter that

of Providence. The possible differences in these data may be summarized as follows: Dr. Chapin's series contains cases appearing after the original case for a period as long as 23 weeks, which is considerably longer than the Baltimore observations. The percent of total cases which occurred at this long interval, however, is so small as to be insignificant in the final result, and it seems likely that the period of our observations would include a very large percent of the total number of secondary cases which Dr. Chapin would have recorded.

The periods covered by the two sets of observations are not simultaneous. However, Baltimore's 1920-1921 death rate is equal to the average for the last 15 years, which would bring the two series into comparison as far as the death rate is concerned as an index of the severity. It may fairly be questioned whether the death rate is an adequate index of severity, since it is the neglected case of diphtheria rather than the severe case that dies.

The following table and the accompanying graph of this same data show that at no time between 1906 and 1917 has the Baltimore death rate from these causes been equal to the rate for Providence. This consistent disparity seems quite significant in the interpretation of the comparative data on the secondary attack rate.

THE INCIDENCE OF DIPHTHERIA, PRIMARY AND SECONDARY CASES, IN MALES AND FEMALES OF EACH SPECIFIED AGE IN FAMILIES WHERE DIPHTHERIA BACILLI WERE FOUND AMONG 100 CLINICAL CASES IN BALTIMORE, NOVEMBER 10-DECEMBER 23, 1920

AGE	CLINICAL CASES			ADDITIONAL PERSONS EXPOSED			KNOWN SECONDARY CASES			SECONDARY ATTACK RATE (%)		
	Male	Female	Total	Male	Female	Total	Male	Female	Total	Male	Female	Total
0 - 4	22	25	47	20	33	53	1	1	2	5.0	3.0	3.75
5 - 9	26	12	38	31	22	53	2	0	2	6.4	0.0	3.75
10-14	3	2	5	20	19	39	1	0	1	5.0	0.0	2.56
15-19	2	1	3	11	15	26	0	1	1	0.0	6.7	3.85
20-29	1	3	4	23	47	70	0	0	0	0.0	0.0	0.0
30-39	0	3	3	51	47	98	0	1	1	0.0	2.1	1.02
40-49	2	0	2	22	21	43	1	0	1	4.5	0.0	2.33
50+	1	1	2	20	34	54	0	0	0	0.0	0.0	0.0
Total	57	47	104*	198	238	436	5	3	8	2.53	1.25	1.84

*Four of the 100 cases were themselves secondary cases.

THE INCIDENCE OF DIPHTHERIA, PRIMARY AND SECONDARY CASES, IN MALES AND FEMALES OF EACH AGE SPECIFIED IN FAMILIES WHERE DIPHTHERIA BACILLI WERE FOUND AMONG 5940 CASES OF DIPHTHERIA IN PROVIDENCE, 1896-1913.

AGE	CLINICAL CASES			ADDITIONAL PERSONS EXPOSED			KNOWN SECONDARY CASES			SECONDARY ATTACK RATE (%)		
	Male	Female	Total	Male	Female	Total	Male	Female	Total	Male	Female	Total
0 - 4	975	847	1822	2126	2115	4241	406	428	834	19.2	20.2	19.7
5 - 9	1071	1210	2281	2041	2007	4048	366	395	761	18.0	19.7	18.8
10-14	400	480	880	1664	1504	3168	165	197	362	9.9	13.1	11.4
15-19	127	165	292	1017	967	1984	48	77	125	4.7	8.0	6.3
20+	249	416	665	7034	7756	14790	108	326	434	1.5	4.2	2.9
Total	2822	3118	5940	13822	14349	28231	1093	1423	2516	7.9	9.9	8.9

A COMPARISON OF THE MORTALITY FROM DIPHTHERIA AND CROUP IN BALTIMORE AND PROVIDENCE, 1906-1917.
RATES PER 100,000

City	Annual Average 1906-1910	1911	1912	1913	1914	1915	1916	1917
Baltimore	14.5	12.0	15.8	15.0	14.8	13.2	10.3	9.8
Providence	28.3	24.7	32.7	29.6	24.1	22.0	29.8	30.8

There would seem to be no constant correlation between the latitude of American cities and their death rates from Diphtheria which might serve to account for these differences. This explanation is not infrequently seen in text books but it is not borne out by the data for the Registration Area.

If one admits a greater severity of diphtheria in Providence than in Baltimore, then Brownlee's analogy in measles might be invoked to explain Providence's excess of secondary cases. Brownlee has shown that in epidemic years measles has a higher rate of spread in non-measles

wards than in other years.* Schamberg assumes this to be true for smallpox but the data are not convincing. After all explanations are allowed in the difference between the incidence of secondary cases in Baltimore and Providence, there remains a significant difference which stands the tests of fact and it is suggested that very likely these comparative secondary attack rates form the best available index of severity in the case of diphtheria.

SPECIAL OBSERVATIONS

There are a few instances brought out during this study which are worthy of note because of significance in the numerous unsolved problems of diphtheria:

An instance was found of a child which had not previously had diphtheria, but who was exposed to diphtheria in a brother in 1919 and at that time this child became a carrier for several weeks. One year following this carrier state this child was again intimately exposed to a playmate who had clinical diphtheria. This time he contracted the usual pharyngeal form. It seems reasonable to suppose that he was immune during his carrier state and this occurrence suggests that naturally acquired immunity to diphtheria may be transient. This child had received no antitoxin previous to his clinical attack. (Case 1, Person 4.)

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*Brownlee, Proc. Royal Soc. Med., June, 1909.

An instance was found of a family in which a boy had a typical attack of diphtheria in November, 1919, with recovery following large doses of antitoxin. In November, 1920 this same boy had a definitely positive Schick. (Case 1, Person 5.) This case is of interest in its bearing on the question of active immunity production when passive immunity is present. Park notes that about 75 percent of clinical diphtheria cases who recover without antitoxin have a positive Schick. It will be of significance to learn whether the administration of antitoxin precludes the development of an active immunity. One instance (Case 1, Person 1) was found of an adult who had diphtheria years ago without antitoxin who is now Schick negative.

Cases 2, 9 and 39 give instances of the existence of nasal infection, sometimes with membrane, but without evidence of toxaemia. There is one doctor in the southern section who commonly finds and reports these cases and, according to the record clerk, such cases are almost never reported by other physicians. It would seem as though these cases were frequently overlooked. Their significance from the viewpoint of spread seems to be large and they justify the routine procedure of nasal cultures. It seems as though the organism might have difficulty in producing toxin in the nasal situation, but Dr. Perkins of Cleveland tells

of having autopsied two cases with only nasal diphtheria.

The use of diphtheria antitoxin therapeutically and prophylactically:

Of the 100 clinical cases studied, antitoxin was given to each one. At any rate, in the few doubtful cases in which antitoxin has not been given at our first visit and in which no subsequent note was made, there was at least antitoxin withdrawn for the patient from the Health Department at the request of the physician, and it is assumed that this was administered.

The contacts of clinical cases received antitoxin prophylactically according to the individual opinion of the attending physician. So far as is known, no physician in this series made Schick tests to determine whether or not antitoxin was necessary prophylactically. In fact we found considerable difficulty in explaining to these physicians the usefulness of the Schick reaction, of which most of them knew nothing. The doses given prophylactically were within the usual limits and quite generally were 1000 units.

The following table shows the number exposed and the number who received antitoxin in several age groups:

Age	Number Exposed	Number Receiving Antitoxin	Percentage Protected
0-4	53	18	34.0
5-9	53	13	24.5
10-14	39	10	25.6
15-19	26	4	15.4
20 & +	265	30	11.3
Total	436	75	17.2

During the course of the field work we have encountered instances of great ignorance of the use of antitoxin. Fortunately, cases of failure to use antitoxin in sufficient quantity are rare. Our small experience indicates that the blame for the late administration in the city usually rests on the parent who failed to summon the physician in time. There are, however, a number of physicians who believe that the protection afforded by antitoxin administered prophylactically is quite permanent and who feel that antitoxin once administered will invariably end an epidemic. Some are using antitoxin subcutaneously to promote the disappearance of diphtheria bacilli from the nose and throat of carriers, both convalescent and contact. It is a noteworthy fact that almost all these families, rich and poor alike, received the free antitoxin distributed from the Health Department.

One instance of a Schick reaction change was found in the case of the writer who has never had diphtheria nor ever been exposed to any extent previous to the present investigation. In May, 1920, six months before beginning this investigation, he was very definitely Schick positive. In January, 1921, eight weeks after beginning this work and after intimate exposure to many cases, he was found to be Schick negative on two successive occasions. The toxin used was found to produce typical positives among susceptibles and the test was done by Dr. Maxcy who had also made the test in May, 1920.

There was found to be present in the nose of this case an organism morphologically identical with diphtheria bacilli of the barred type, but which was found to be avirulent in one culture taken January 7th. This same form persisted in the nose without any symptoms until March 1st, after which two cultures were negative. This finding suggests the role which avirulent bacilli may play in the acquiring of natural active immunity. Several observers have shown that medical students have fewer positive Schicks at the end than at the beginning of a school year, and the supposition is that these men have been caught, so to speak, when they were acquiring

the natural immunity which so many adults have. Although this single instance may be unrelated to the carrier state of an avirulent organism, it is at least suggestive that the mechanism of active immunity may depend on the presence of the diphtheria bacillus, possibly of the avirulent variety.